Six Sigma Project Charter

Project Title: Angus Louisiana Energy Reduction

Project Impact/Strategic Alignment: The impact of the inefficient operations causes the site to purchase >10% more fuel gas to meet steam demand. This project supports the HC&E 3-5 year objectives (MI Plan 3.3 and 5.4) for reducing site energy purchases and greenhouse gases associated with Climate Change initiatives as well as Angus cost reduction objectives.

Opportunity Statement: This project has two separate opportunities. The first opportunity is to optimize the temperature of the steam provided by the current reducing station because it is higher than that required by the process and various steam drivers it supplies. The second opportunity involves the overall combustion control of the boilers. Current control is less than optimal because of permit limitations, an obsolete control system, and equipment aging.

Project Scope & Boundaries: This project will involve the optimization of the primary boilers (#6 and #7) operation/maintenance and the 585/285# steam reducing station at the powerhouse without exceeding any boiler air permits.

Project Goal/Objectives: Evaluate the constraints for operating the Boilers #6 and #7 at optimum efficiency focusing on variability, remove obstacles for optimum operation and put a control plan in place to ensure the gains are sustained. Evaluate the benefits of optimizing the performance of the 585/285# steam and make hardware and/or operational changes to reduce site energy usage.

Timeline:

Measure:	02 May 2001 - 29 June 2001	Analyze:	29 June 2001 - 31 Aug 2001
Improve:	31 Aug 2001 - 31 Oct 2001	Control:	31 Oct 2001 - 30 Nov 2001
Realization:	30 Nov 2001 – 30 Nov 2002		

Deliverables: Deliverables include Boilers #6 and #7 and steam letdown station optimization. Up to a 7.5% reduction in purchased fuel will be demonstrated by analyzing boiler fuel usage before and after optimization of the boilers/steam letdown station. **This represents a savings of approximately $300M/year for a $3.20/MMBtu fuel price.**

Team Characteristics/Composition: Mike Mulherin (Black Belt), John Quillman (Sr. Util. Engr.), Danny Hunt (Util. Supv.), Steve Dilmore (Util. Operator), Ricky Hayes (Instrument Specialist), Ron Poindexter (EH&S), Karen Kay (Local Champion), Doug Sullivan (Master Black Belt), Ernest (Process Owner), Darryl Rogers (ES Finance)

Key Inputs/Outputs

Inputs	Process	Outputs
Fuel Flow Burner Pressure D/A Steam Flow PRV Steam Flow	**Match Boiler(s) Load to Steam Demand**	Steam Flow Steam Pressure Steam Temperature
Waste Inventory	**Determine need to burn waste & adjust flow rate**	Waste Flow Burner Pressure Atomizing Pressure Pump Pressure
Waste Flow	**Select Boiler(s) Load Mix**	Steam Flow
Steam Flow Air Setpoint	**Adjust airflow to meet NOx, CO & Excess O2**	CO NOx **Excess O2 %**
Upstream Temp./Press. PRV Setpoint	**Adjust Reducing Steam Control Valve Flow/Pressure**	PRV Flow **Downstream Temp.**/Press.

Boiler Excess O2% and PRV Downstream Temperature are Critical to Cost

STARTS HC&E HERE
COMPETITIVE ADVANTAGE

SIX SIGMA

Measure

Angus Boiler Fuel Baseline

Establish Baseline Year:

- ***Steam Production Rates***
- ***Fuel Consumption Rates***
- ***Calculate Fuel to Steam Ratio***
- ***Defect - Boiler Excess O2% > 7%***
- ***Measure Steam Temperature and Model D/S requirements***

Steam Temperature is not currently measured. Control of the Steam Temperature would reduce Boiler Fuel and result in 4% reduction.

Targeted Reduction: 7.5%

Boiler #6 % Excess O2

Current Sigma:	**-0.30**
Target Sigma:	**1.60**

Boiler #7 % Excess O2

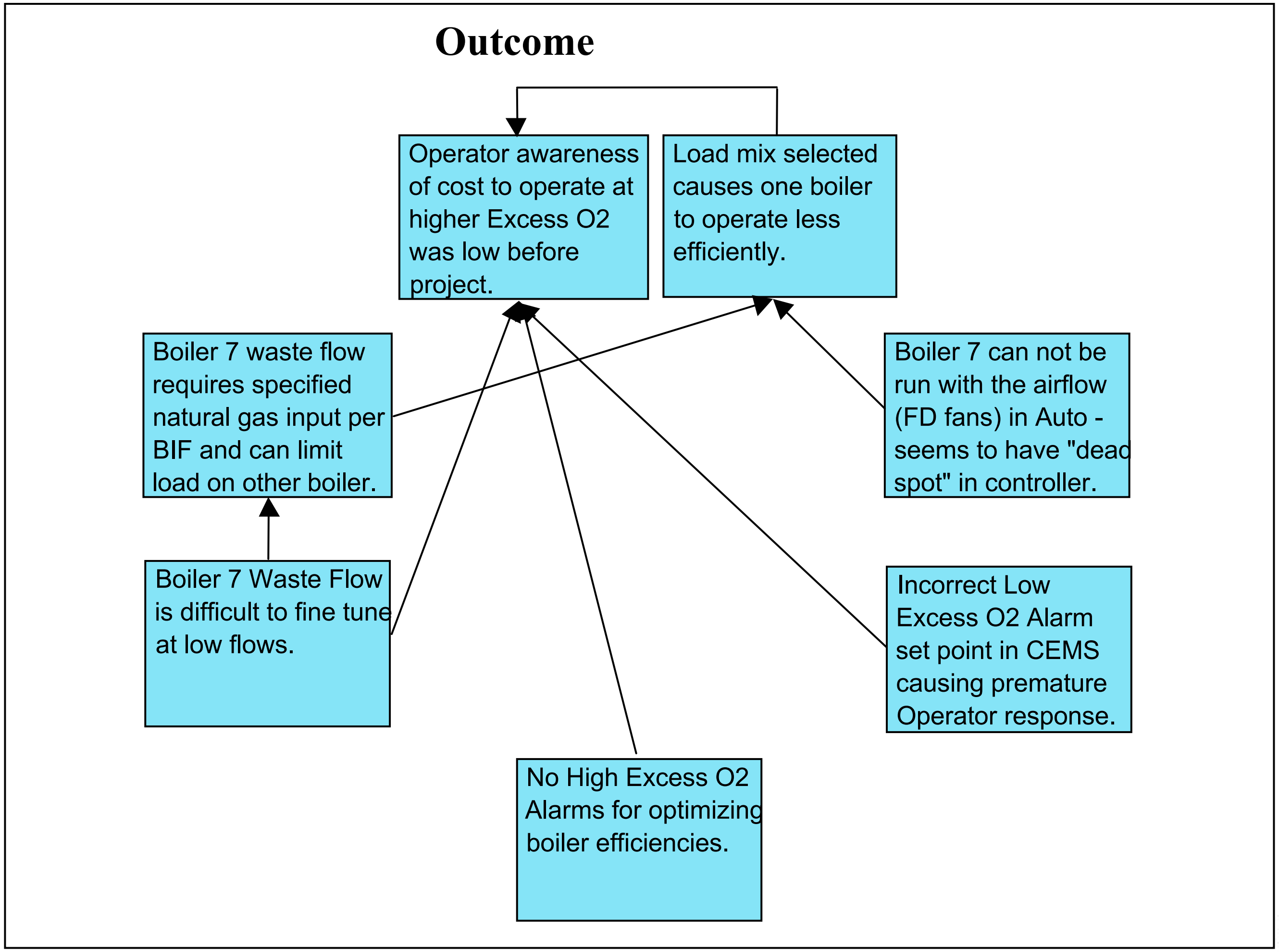
Current Sigma:	**-0.40**
Target Sigma:	**-0.02**

Sigma shift of 1.0 represents 70% Defect Reduction

Analyze

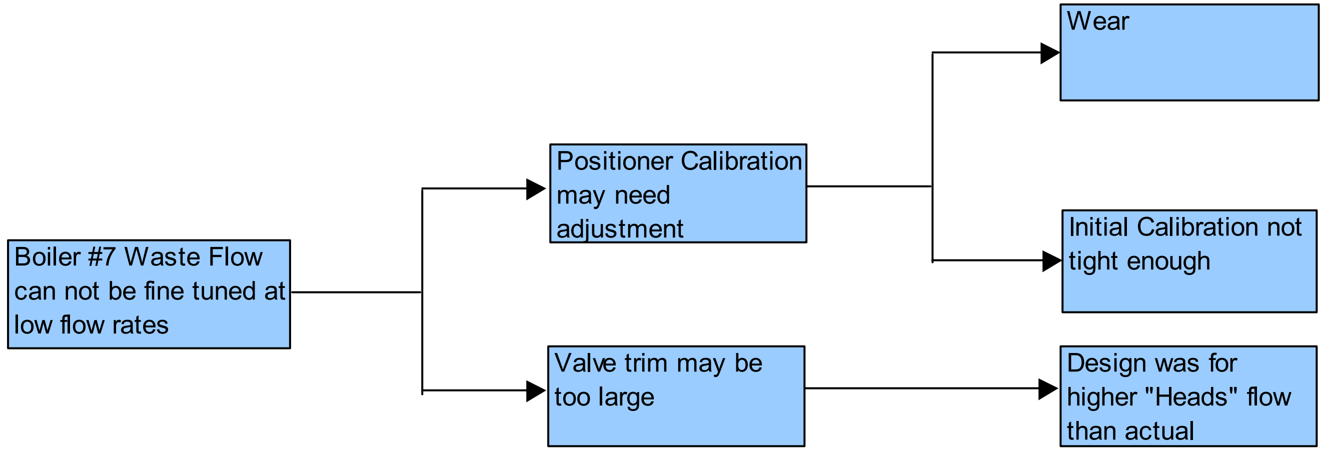
Interrelationship Diagram

How are the Most Probable and Actionable Causes for not Operating Boilers #6 and #7 at Optimum Efficiency related? Fix the Obvious Possible Causes and use the "5" Why's to Narrow the other Causes to Root Causes.



Drilling Down for Potential Root Causes

Boiler Waste Flow was one of the Key Input Variables identified as affecting the % Excess O2 Exiting the stack. The Waste Flow control for Boiler #7 was also identified by the Operators as needing improvement.



Drilling Down for Potential Root Causes

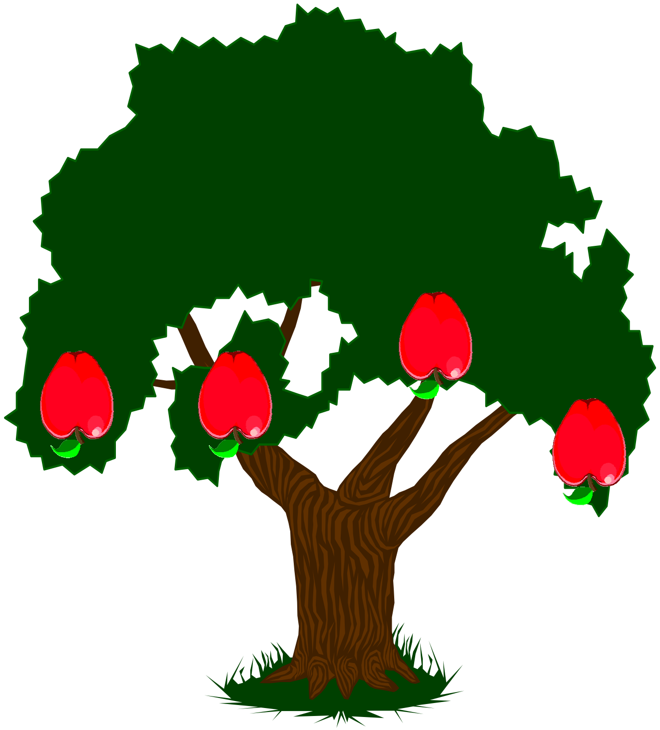
Boiler #7 can not currently be run in automatic; while a manual mode is often chosen for operational reasons, the air controller and associated linkage could use an overhaul. Additionally, the main fuel control valve is oversized, making fine tuned control difficult.

- Can not run Boiler #7 fuel or air in automatic.
  - Air controller seems to have "dead spot" in it that hampers control.
    - Bearings and/or mechanical linkage are worn.
    - Air flow controller needs to be checked and calibrated.
  - At most rates fuel flow < 40% of range and main valve is not far open.
    - Original design of main fuel valve was for low Btu gas and no Heads burning.
    - Original design also includes bypass control valve for start-up.

Note: Boiler #6's Air control system was also found to be in need of an overhaul. Similarly, the fuel valve was oversized in Boiler #6, as well.

SIX SIGMA

"Fix The Obvious"



<u>Low Hanging Fruit</u>

✓ Communicate to Operators the Cost Impact of not Operating the Boilers at Optimum Efficiency

✓ Ensure Low Alarm Set points for % Excess O2 are established to Warn Operators when approaching the Air Permit Limits

✓ Establish High Alarm Set points for % Excess O2 on an Alarm System other than the CEMS for Boiler Efficiency Optimization

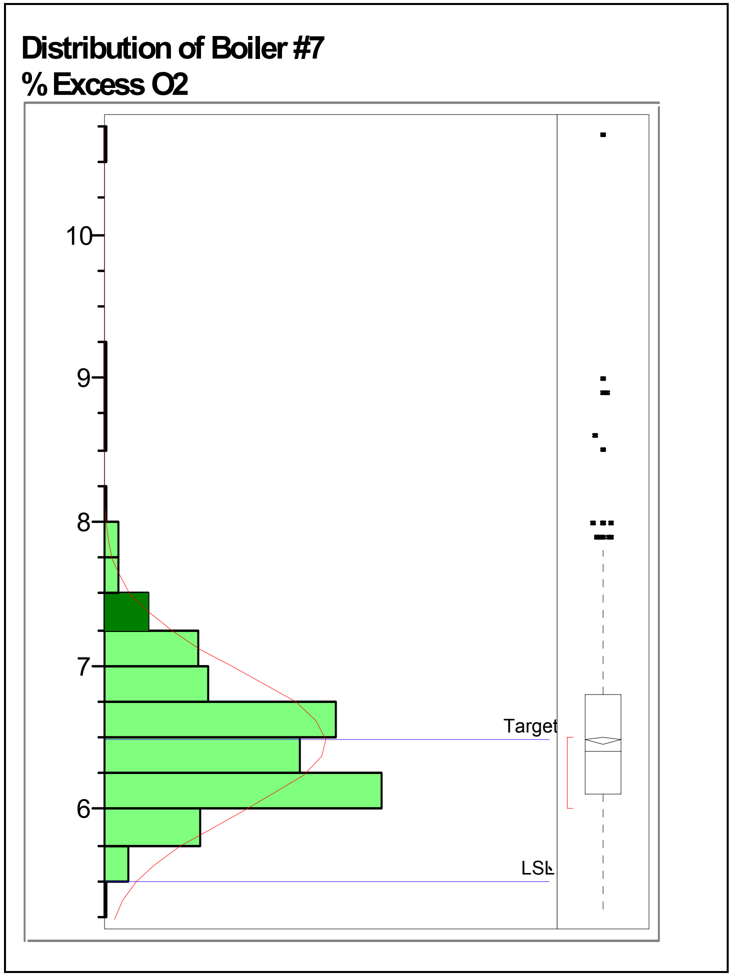
✓ Investigate Operating Boilers at Pressures Lower than Design to reduce Energy Losses Across PRV

✓ Install New Desuperheating Nozzle and Desuperheating Water Control Valve to Allow Steam Temperature Control across PRV - during November 2001 shutdown

Analyze

Savings Prior to Realization

Execution of the Communication Plan with the Operators and a trial run on the Boilers at lower operating pressures during August, resulted in an average of 3.9% Fuel Gas Savings over the first four months of the project.



Increased Operator Awareness of the Costs associated with Operating the Boilers at high % Excess O2 allowed a reduction of 0.8% Excess O2 or about a 9% improvement for Boiler #7.

Accumulated Savings Prior to Realization has Reached $60M

1X Target - 7.5% Savings
2X Target - 10% Savings

Operating Discipline

Operating Discipline Documents, Tables and other Guidelines were Developed for Operations to Manage the Key Changes Implemented with the Selected Solutions

Boiler Operating Pressure Guidelines

Parameter	Low Alarm	Target
600# Steam Header Pressure	450 psig	475 psig
Boiler Feed Pump Discharge Pressure	600 psig	675 psig

Boiler Operating Pressure	Maximum Capacity (approximate)
600 psig	135 klbs/hr
575 psig	129 klbs/hr
550 psig	123 klbs/hr
525 psig	117 klbs/hr
500 psig	111 klbs/hr
475 psig – Target Pressure for Steam Header	105 klbs/hr
450 psig	100 klbs/hr
425 psig	94 klbs/hr
400 psig	89 klbs/hr

Boiler Excess O2 Operating Guidelines

Boiler	Low Permit Limit - % Excess O2	High Permit Limit - % Excess O2	Low Alarm - % Excess O2	% Excess O2 Target Value	High Alarm - % Excess O2
Boiler #6	4.3%	10.0%	4.8%	5.5%	7.0%
Boiler #7	5.5%	10.0%	5.7%	6.0%	7.0%

Desuperheater Operating Temperature Guidelines

Desuperheater Downstream	Low Alarm Limit	Target Steam Temperature	High Alarm Limit
Steam Temperature	533 F	600 F	666 F

STARTS HC&E HERE — COMPETITIVE ADVANTAGE

SIX SIGMA

Boiler Performance

	Before Improve		After Improve	
	DPMO	**Long Term Sigma**	**DPMO**	**Long Term Sigma**
Boiler #6	616,162	-0.30	407,673	0.23
Boiler #7	657,084	-0.40	39,207	1.76
Combined Performance	**636,623 (Avg.)**	**-0.35**	**223,440 (Avg.)**	**0.76**

Boiler #6 - 34% Defect Reduction

Boiler #7 - 94% Defect Reduction

Overall Sigma Improved for Both Boilers from -0.35 to 0.76!

Improve

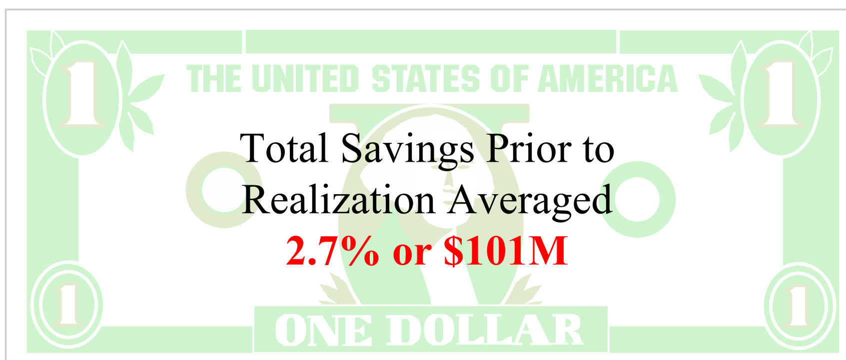
Hardware Changes

The “Heads” control valve trim was replaced and a new Desuperheater was placed into service. Data was taken to measure the performance improvement. The data matched quite well the modeling done early on the project.

Typical Desuperheater Savings					
Fuel Cost ($/MMBtu)	Steam Flow (klbs/day)	Downstream Steam Temp (deg F)	DSW Flow (klbs/day)	Fuel Savings (MMBtu/day)	Fuel Savings ($/day)
$ 3.20	3000	600	120.0	144.0	$ 461

Projected Annual D/S Savings are 3.8% Based on Initial Data

Total Project Savings



Total Savings Prior to Realization Averaged **2.7% or $101M**

Control Plan

A Control Plan was developed and Implemented along with the Associated new Operating Discipline, Control and Savings Charts.

Dow Six Sigma Control Plan

Process Description **Angus Powerhouse Steam Generation and Distribution**		Critical to Quality Requirements	Current Sigma Level	Key Output Variables	Revision # **5**	Date
Process Owner: **Ernest Green – Production Leader**	Process Customer: **Angus Process Plants – Basics, Derivatives, Acid and Crystals Plants**	• **% Excess O2** • **PRV Downstream Temp.**	**0.76 (Defect is % Excess O2 greater than 7.0%)**	• **% Excess O2 – Boilers 6 & 7** • **PRV Downstream Temp.**		**4/2/02**

Process Flow Chart		Checking						Miscellaneous Information
Dept/ Person / Step/ Time	Operators	Indicators	Performance Standards	Item	Frequency	Responsibility	Contingency Plans	Procedures Standards Etc.
		KIVs, KPVs, KOVs	Specs, targets, control limits	What to check	When to check	Who checks	Corrective actions	
Set HP Steam Header Press.	KIV → Match Boiler(s) Load to Steam Demand; KOV1	KIV: Steam Demand KOV1: HP Steam Header Pressure	Target: 475 psig	Digital Readout	4 times/shift (once every 2 hours)	Board Operator	Adjust if no other limitations (ie: High Steam Demand)	Boiler SOP's in Control Room and Project Boiler Pressure OD
Set Waste Burning	Determine need to burn waste & adjust flow rate	KPV1: Boiler #7 Heads Flow (gpm) KPV2: Boiler #7 Fuel Flow	Tank Level: ≤30% ≥ Fuel Flow Req'd by Chart	Record Heads flow from CEMS Record from CEMS & Required from Chart	4 times/shift (once every 2 hours) 4 times/shift (once every 2 hours)	Board Operator Board Operator	Adjust if no other limitations Adjust if no other limitations	Boiler SOP's in Control Room Fuel vs. Heads Flow Chart
Optimize Boiler Load Mix	Select Boiler(s) Load Mix	KPV's 3 & 4: Boiler #6 & #7 Steam Flows	Match Loads as Much as Possible	Record Steam Flows from CEMS	4 times/shift (once every 2 hours)	Board Operator	Adjust if no other limitations (ie: Fuel vs. Heads Flow Chart)	Boiler SOP's in Control Room & Project Boiler Load Mix OD
Optimize Airflow	Adjust airflow to meet NOx, CO & Excess O2; KOV's 2 & 3	**KOV's 2 & 3: Boiler #6 & #7 % Excess O2**	**Boiler #6** Target: 5.5% Limits: 4.3 – 10% **Boiler #7** Target: 6.0% Limits: 5.5 – 10%	Record from CEMS	4 times/shift (once every 2 hours)	Board Operator	Adjust if no other limitations (ie: Low Steam Demand)	Boiler SOP's in Control Room & Project % Excess O2 OD
Set D/S Outlet Temp.	Adjust Reducing Steam Control Valve Flow/Pressure; KOV4	**KOV4: D/S Outlet Steam Temperature**	Target: 600 F	Controller	4 times/shift (once every 2 hours)	Board Operator	Adjust if no other limitations	Boiler SOP's in Control Room & Project D/S OD

Key Learnings

- Increasing Awareness and Understanding Will Result in Gains
- Data Analysis Can Yield Unexpected Causes - Heads Control Valve
- A Pilot Rather than Experiment can be Used to Validate Improvements
- Not All Improvements are Measurable - Lower Boiler Operating Pressure
- Project Progress is Dependent Upon Plant Schedules/Shutdowns
- Use of the Correct Sigma Calculation is Key - Permit Limits vs. Defects
- New Fuel vs. Heads Chart and BIF Interpretation Changed the Projected Savings
- It's Critical to Involve Process Owner and Local Champion throughout Project and to have an Effective Project Hand-off
- Build Checks and Balances in the data to Make it easier to Pinpoint discrepancies

Realization

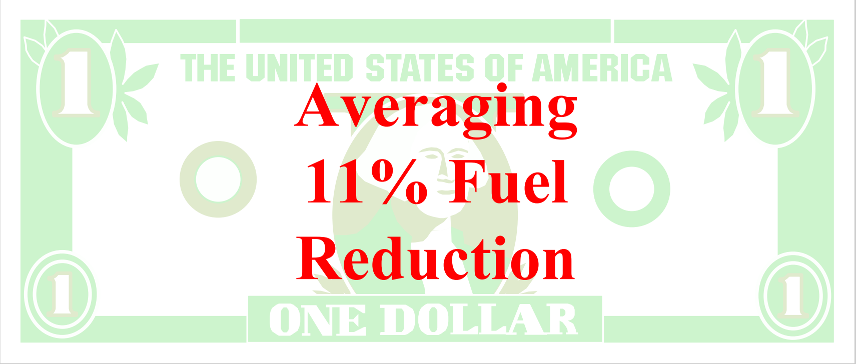
Executing the Control Plan

The Board Operators, Utilities Supervisor, and Utilities Engineer have done an excellent job executing the control plan and made it possible to far exceed the final project projections through the first 8 months of realization.

Final Projections

1X Target - 6% Savings
2X Target - 7.5% Savings

Project Savings to Date \$474M Expect to Exceed \$600M



Averaging 11% Fuel Reduction